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MELANISM IN *PHIGALIA TITEA* (CRAMER) (LEPIDOPTERA: GEOMETRIDAE): A FOURTEEN-YEAR RECORD FROM CENTRAL MASSACHUSETTS

Theodore D. Sargent

Department of Zoology, University of Massachusetts,
Amherst, Massachusetts 01003

Abstract.—The melanic morph of *Phigalia titea* (Cramer), "*deplorans*" (Franclemont, 1938), comprised 18.7 percent of 3,906 specimens collected at various light sources at a single location in central Massachusetts between 1968 and 1981. There were no discernible trends in melanic frequency over that period. Three different light sources (incandescent, fluorescent and mercury vapor) yielded similar estimates of melanic frequency. There was a decline in melanic frequency late at night (after 2300 hours), and an increase in melanic frequency during the second half of the flight season. The implications of these results are briefly discussed.

This report summarizes information on the incidence of melanism in *Phigalia titea* (Cramer) (Lepidoptera: Geometridae) as determined by light-source collecting at a single location in Leverett, Franklin County, Massachusetts from 1968–1981. Previous papers have dealt with part of this period (1968–1973) (Sargent, 1971, 1974), and the present paper extends and elaborates on the overall record.

LOCALITY AND METHODS

Male *P. titea* were collected at several light sources about my home in Leverett. (Female *P. titea* have only rudimentary wings, do not fly, and are not included in any of the recorded data.)

My home is located in an extensive, mixed deciduous woodland dominated by 40-year-old oaks (*Quercus alba* L. and *Q. velutina* Lam.) and hickories (*Carya ovata* (Mill.) and *C. glabra* (Mill.)). Other trees with substantial representation include birches (*Betula papyrifera* Marsh. and *B. lenta* L.), pine (*Pinus strobus* L.) and hemlock (*Tsuga canadensis* L.). Understory shrubs include mountain laurel (*Kalmia latifolia* L.), viburnums (esp. *Viburnum acerifolium* L.) and blueberries (inc. *Vaccinium corymbosum* L. and *V. vacillans* Torr.), reflecting an acidic soil. The area shows little evidence of air-borne pollution, as epiphytic lichens are common on tree trunks that are themselves not noticeably darkened by soot.

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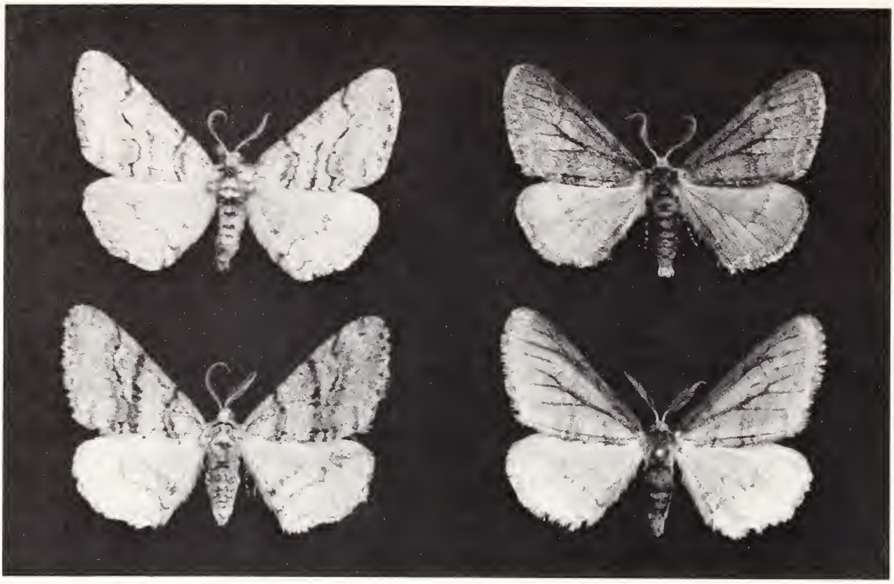

Fig. 1. The typical (left) and melanic (right) morphs of *P. titea.* The upper specimens are representative of the Leverett population. The lower specimens are an unusually dark typical (left) and an unusually light melanic (right). Approximately life-size.

Four incandescent spotlights (Westinghouse outdoor projector, 150-watt), a fluorescent blacklight tube (General Electric F15T8 BL, 15-watt), and a medium-pressure, mercury-vapor discharge lamp (Atlas MB/U, 125-watt) were all used at various times, and these light sources were carefully distinguished in the records. Generally, the lights were checked on several occasions during the night, and the time, as well as the numbers of typical and melanic *P. titea* present, were recorded. An effort was made to capture all of the assembled moths on each visit to a light in order to minimize the possibility of counting individuals on more than one occasion. The capture moths were sacrificed, except for some that were color-marked and released as part of a mark/recapture study during 1969 and 1970 (see Sargent, 1971).

Most collected *P. titea* were easily assignable to one of two morph categories: "typical" (light gray ground with strongly contrasting black lines), or "melanic" (="*deplorans*", Franclemont, 1938) (blackish overall, with only a trace of the black lines). Occasional specimens, especially worn individuals, were somewhat intermediate, but these were assigned to one or the other category on the basis of whether the scales on the abdomen were light gray ("typical") or blackish ("melanic") (Fig. 1).

(The division of specimens into only two categories on the basis of appearance is undoubtedly an oversimplification in terms of reflecting the underlying genetic and/or environmental bases of melanism in this species.

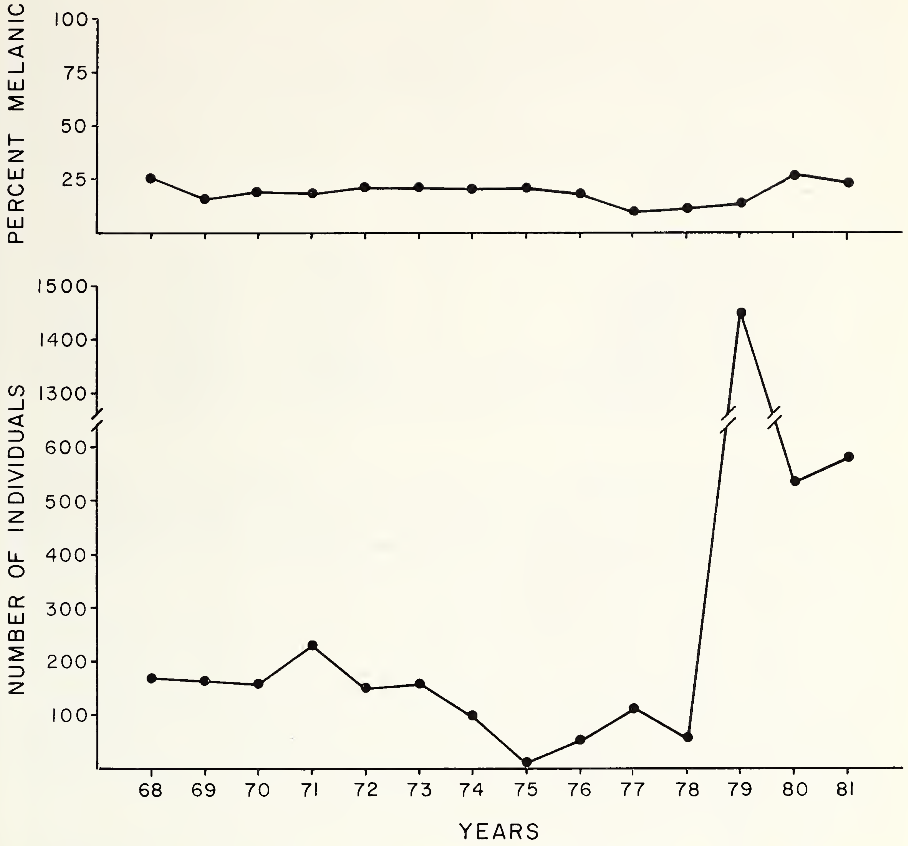

Fig. 2. The total numbers of *P. titea* taken at light sources in Leverett, Massachusetts for the years 1968–1981 (below), and the percentage melanic for each of these yearly samples (above).

However, given our lack of knowledge regarding these underlying factors, and further uncertainty regarding the effects of wear on phenotypic appearance, it seems pointless to attempt a finer classification at this time.)

RESULTS

A total of 3,906 *P. titea* was taken at the various light sources over the 14-year period, 1968–1981. Of that total, 730 individuals, or 18.7 percent, were melanic. The yearly sample sizes varied considerably, but the corresponding percentages of melanics were relatively constant, and there were no long-term trends of either increasing or decreasing melanic frequency (Fig. 2).

Light sources. The three different light sources used in this study (incan-

Table 1. The numbers of typical and melanic individuals of *P. titea* taken at various light sources during periods of simultaneous operation.

Year	Light sources	Numbers		P*
		Typical	Melanic	
1971	Spotlights	118	24	>0.50
	Blacklight	71	17	
1979	Spotlights	652	110	>0.70
	Blacklight	574	92	
1972	Spotlights	22	5	>0.40
	Blacklight	41	15	
	Mercury vapor	54	12	

* Probabilities based on chi-square contingency tests.

descent spotlights, fluorescent tube, and mercury vapor bulb) were apparently sampling identically, as the frequencies of typical and melanic *P. titea* taken were not significantly different when compared for any of the sources during periods of simultaneous operation (Table 1).

Time of night. In a previous paper (Sargent, 1971), I suggested that melanic *P. titea* might occur at their highest frequency during the early hours of the evening. That suggestion was not supported by the more extensive data reported here (Table 2). However, there was a decline in the frequency of melanics taken late at night (after 2300 hr) (chi-square, 2 × 3 contingency test = 5.94; $P \cong 0.05$), suggesting that melanics may have a somewhat different daily flight period (shorter, if not earlier) than typicals.

Seasonal effect. No seasonal effects were discernible in the data reported previously with respect to the proportions of typical and melanic *P. titea* taken (Sargent, 1971). Analysis of the current data reveals, however, that significantly more melanics were taken over the second half of the season each year ($^{370}/_{1,768}$, 20.9%) than were taken over the first half of the season ($^{354}/_{2,079}$, 17.0%) (chi-square 2 × 2 test, $P < 0.002$) (Fig. 3B). This effect is

Table 2. The numbers of typical and melanic individuals of *P. titea* taken at various times of night (based on data from nights when sampling was repeated no less than hourly) for the six years when *P. titea* was most abundant at the Leverett location.

Time of night	Numbers		% melanic
	Typical	Melanic	
<2100 hr	586	141	19.4
2100–2300 hr	560	148	20.9
>2300 hr	267	45	14.4

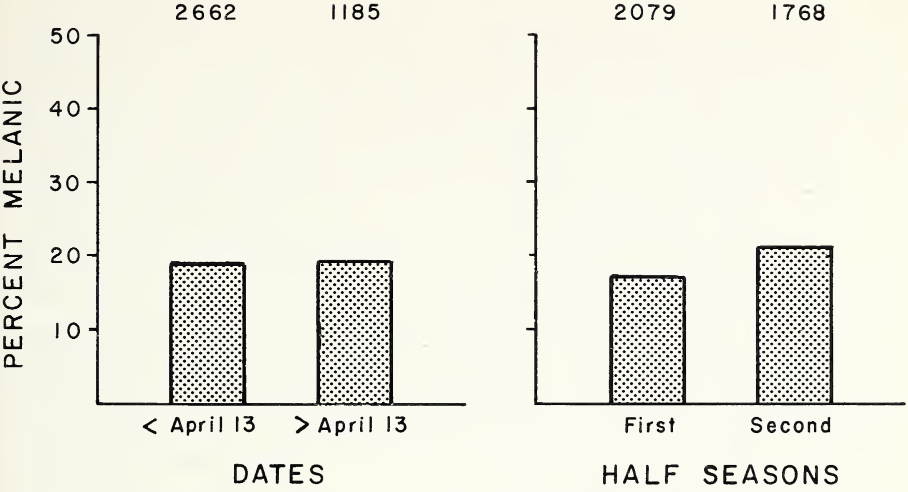

Fig. 3. The percentage of melanic individuals of *P. titea* taken before and after April 13 (left) and during the first and second half of the flight season (right), summed for the years 1968–1981 in Leverett, Massachusetts. The total numbers of individuals taken are given above the bars.

not apparent when the data are analysed by calendar dates (Fig. 3A), suggesting that the seasonal effect is not based on differential responses of the two morphs to extrinsic environmental factors (e.g., temperature, daylength), but rather reflects some intrinsic difference between the morphs with respect to either their physiology (e.g., development rates, longevity) or their susceptibility to predation.

DISCUSSION

Aside from a single, very early record from West Roxbury, Massachusetts (Minot, 1869), melanic *P. titea* were first reported from most localities in eastern North America from about 1915–1960 (Owen, 1962). Minot described his early specimen as a new species, *P. strigataria,* but Franclemont (1938) correctly identified the melanic as a morph of *P. titea,* naming it "*deplorans*". Interestingly, by 1962, "*deplorans*" had not been noted in certain industrial areas (e.g., Pittsburgh, Chicago) where melanic *Biston cognataria* (Guenée) had already become quite common, and at that time it was estimated that "*deplorans*" made up no more than 10 percent of any *P. titea* population in North America (Owen, 1962). Few other data are available until the present records which indicate that the melanic frequency of *P. titea* in central Massachusetts has remained stable at close to 20 percent of the population for the past 14 years.

I have previously pointed out that the area in which these records have been obtained shows little discernible evidence of industrial air pollution, and Owen (1962) noted that *P. titea* was unusual in that the initial reports of melanism were not from industrial centers. Thus, the bases for melanism in *P. titea* remain obscure, although similar problems exist with respect to explaining melanism in the closely related *P. pilosaria* (Schiff.) in Britain (Lees, 1971, 1981). It seems certain that factors other than selective predation based on crypsis are involved in these cases, as they seem to be in *Biston* in both the rural central Appalachians in this country (West, 1977) and southern Britain (e.g., Steward, 1977).

Evidence for different daily flight periods for the typical and melanic morphs of a species has not, to my knowledge, been reported previously. Such a difference would be detected only if sampling were carried out as here with *P. titea,* i.e., at intervals throughout the daily flight period of the species, with all of the moths collected at each sampling time. The significance of the apparently earlier flying of melanics than of typicals in *P. titea* is not immediately apparent, though it may be related in some way to the differences one would expect to find in the warming and cooling characteristics of dark, as opposed to light, insects (see e.g., Watt, 1968).

A tendency for melanics to become more common later in the season, as reported here for *P. titea,* has been reported for other species as well. Thus, Bishop, Cook and Muggleton (1978) described an abrupt increase in the frequency of the melanic "*nigra*" morph of *Gonodontis bidentata* Clerk towards the end of the season at two locations in northwest England. These authors attributed this effect to a later emergence of the "*nigra*" morph. Increasing melanic frequency over the season has also been reported in *Cleora repandata* L. in the Scottish Highlands, though in this case the effect has been attributed to selective predation favoring the melanics (Kettlewell, 1973, p. 86).

There is some evidence to suggest that melanics may have slower development rates than typicals in some species (e.g., *Spodoptera exigua* Hubn. (Poitout, 1973), and *Biston betularia* (Kettlewell, 1973, p. 85)). There is no evidence on this point for *P. titea,* but Lees (pers. comm.) has detected no differences between the development rates of typical and melanic *P. pilosaria* in his extensive rearing of that species.

Another factor that could lead to higher melanic frequencies later in the season is an increased viability of melanics relative to typicals in the adult stage. I am aware of no studies on adult viabilities in an industrial melanic species, though there is evidence for a greater viability of the larvae of melanics in certain cases (e.g., *Menophra abruptaria* Thunb. (Onslow, 1921), and *Cleora repandata* (Ford, 1940)). Kettlewell (1973, p. 78), however, found the evidence for differential viability of larvae of the morphs in industrial melanic species "unconvincing", and the matter needs further investigation.

The possibility remains that the increased frequency of melanic *P. titea* later in the season is due to selective predation that favors the melanics. If this were so, it seems unlikely that it would be based on crypsis, as the area in which these studies were conducted is, as previously noted, visibly rural. Furthermore, experimental tests have shown that melanic *P. titea* prefer light backgrounds (Sargent, 1969), a tendency that would seemingly place them at a cryptic disadvantage.

Other possible bases for differential predation on the morphs of *P. titea* should be explored. Whittle et al. (1976) obtained evidence that bats take more typical than melanic *B. betularia,* and this possibility should not be overlooked in *P. titea,* particularly in light of the evidence that melanics of this species may fly earlier in the evening or for a shorter period of time than typicals. Other matters that should be investigated include the relative palatabilities of typical and melanic *P. titea* to potential predators, and the possibility of behavioral differences between the morphs in reacting to predator attacks.

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